Drilling and Borehole Instrumentation

The Drilling and Borehole Instrumentation team originated with the Hot Dry Rock Geothermal Energy Project, established in 1973, in which EES (and our predecessors) successfully addressed the challenges of drilling in severe geologic environments. Building on this heritage, we are now contributing to the effort to enhance the scientific basis for improving oil and gas field exploitation through our Advanced Borehole Seismic Geodiagnostics project. Our fluid-identification logging tool adapts a national-security technology (originally developed at Los Alamos for munitions inspection) to the problem of improving the productivity of oil wells. Our rock-melt drilling technology explores applications for environmentally benign, simultaneous drilling and well casing; and our NASA-supported Martian drilling project advances the frontiers of unconventional rock penetration technology. We have also made significant advances and cost reductions in subsurface rock-mass characterization by integrating our small-hole drilling and instrumentation projects (such as microhole logging and coiled-tube microhole drilling).

Advanced Borehole Seismic Diagnostics

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The National Petroleum Council and various other industrial organizations have identified the need to improve the acquisition and interpretation of seismic data from fracture-dominated reservoirs. To this end, EES Division has been a leader in developing instrumentation and processing methods for mapping reservoir fractures at distances of hundreds of meters from boreholes. We are analyzing reservoir microseismicity (extremely weak seismic signals arising from the release of strain in the reservoir) and investigating the relationship of strain-release fractures to reservoir production. Using borehole instruments developed at Los Alamos, we can now determine the nature, location, and extent of these fractures, which will indicate how natural or hydraulically produced fractures contribute to oil or gas field production in any reservoir where seismicity is present. Reservoir seismicity, which often may only be detected by using sensitive instruments deployed in boreholes, is the clearest indicator of fractures that significantly influence reservoir production.

Fluid-Identification Logging Tool

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An important problem faced by the oil industry is the influx of water into production wells. The ability to identify these water-producing zones so that perforations can be sealed will significantly improve the economics of oil production. We are developing a wire-line deployable logging tool to identify water-producing zones; this tool, based on technology originally developed at Los Alamos to noninvasively determine the contents of chemical warfare munitions, is called swept-frequency acoustic interferometry (SFAI). SFAI may be thought of as the setting up of standing waves in a fluid-filled cavity using external excitation, while at the same time measuring the amplitude, frequency, and peak width of resonances of the fluid-cavity system. SFAI measurements can be used to derive multiple physical properties of the material in the cavity, including sound speed, sound absorption, frequency dependence of sound absorption, and fluid density. We are working on incorporating SFAI into a logging tool that will be used to rapidly characterize fluids entering wells through perforations. We have established the feasibility of using SFAI for logging tool measurements and completed a prototype fluid sampling and measurement tool subassembly. Currently, we are completing the design and fabrication of the tool's electronics subassembly, and will be testing the combined electronics and mechanical assemblies in a multiphase flowing well simulator.

Adapting Rock-Melt-Drilling Technology

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Just about every possible method to make a borehole has been tried over the last several decades. Despite these efforts, rotary mechanical drilling, with gas or liquid cooling and particulate conveyance, remains the method of choice for most applications. Some of these other methods have found niche applications, however, and one for which we are finding increasing use is rock melting. This technology was invented at Los Alamos in 1965 and rapidly developed in the mid-1970s under the Subterrene Project. In rock melting, a refractory bit is pressed (without rotation) against the ground, and the rock or soil it contacts is heated past its melting point by thermal conduction from the hot bit. The mechanically weak melt is displaced and forms a consolidated glass lining around the borehole which, when cooled, structurally supports the borehole, preventing collapse and effectively replacing metal or other tubular casing commonly needed in rotary mechanical drilling. Recently, we resurrected the Subterrene rock-melting technology and are adapting it for new customers in industrial, defense, and scientific areas. One scientific application, a joint development with NASA, is to adapt new drilling technologies for deep sampling of the Martian subsurface.

At the present time, we are evaluating a range of possible drilling methods, including rock melting. We have set up a laboratory to test bit designs at bench-top scale, developed a new finite-element modeling effort to capture the full thermomechanical melting and rock penetration physics, and designed drilling components adapted to our field-coiled-tubing test bed.

Microhole Logging Tools

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This is a multiyear project for the design, testing, and evaluation of a suite of miniaturized logging tools for measurement of formation properties with wireline tools capable of running in microholes. We currently are prototyping wireline tools that will ultimately be adaptable to a measurement-while-microdrilling system and will measure (1) borehole inclination and azimuth (a trajectory surveying tool); (2) natural and spectral gamma; and (3) resistivity via an electrode, focussed current, or induction device or a simple combination thereof. The tools will be patterned after nonproprietary designs of conventional tools we obtained from the project's industrial participants and subcontractors; they will incorporate state-of-the-art technologies available at Los Alamos and in the industrial sector. The resistivity tool will be designed to take advantage of the capability to drill underbalanced microholes with very low volume "designer" drilling fluids, which will enhance the resistivity contrast of target formations. In successive years, these tools may be incorporated into bottom-hole drilling assemblies. We will also use other conventional logging tools for miniaturization and prototyping. Environmental testing of the tools will occur in existing small pressure vessels and conventional wells, and we will verify the performance of the logging tools in microholes drilled in close proximity to wells for which conventional logs are available. Based on our experience to date, we expect that the unit cost of a tool developed in this project will be a small fraction of the cost of its full-sized equivalent.

Coiled-Tubing-Deployed Microdrilling

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The capability to conduct reservoir exploration, characterization, and monitoring from wells as small as 1 inch in diameter will soon be technically within reach. We believe that exploration using microholes is a viable concept if the costs can be kept low and the micrologging tools are available to run a basic formation evaluation suite. Once the microdrilling infrastructure is in place and the technical know-how is established, according to a recent analysis microholes can be produced for 1/5 to 1/10 the cost of conventional-sized holes.

To support the microdrilling concept, we are conducting laboratory and modest field demonstrations of the critical subcomponents of a coiled-tubing-deployed microdrilling system. We have assembled a coiled-tubing-based drilling system capable of drilling 2-3/8-in.-diameter (and smaller) microholes to 800 ft deep, and we successfully demonstrated shallow microdrilling to 550 ft in unconsolidated lakebed sediments in 1999. Numerous minor difficulties were encountered, but none challenged the feasibility of the microdrilling.

Our results indicate that coiled-tubing-deployed microdrilling can be applied to many more drilling situations in the oil fields and rocks than have been drilled to date. We have also demonstrated that microdrilling can now be used at depths that are of greater interest to the oil industry.

It may be possible (with adequate funding and industry support) for a 5,000-ft-depth microhole to be drilled within three years. We hope to maintain the current momentum in shallow microdrilling development and to provide a realistic evaluation of the feasibility of drilling still deeper microholes.

Mars Drilling Plan and Engineering Research

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High on the list of science objectives within the ongoing planning for Mars exploration is the search for past or present life. Astrobiologic thinking is that, by analogy with Earth, life as we know it requires the presence of liquid water. Therefore, a crosscutting strategy in the exploration of Mars is to "follow the water." There is abundant and growing evidence from surface landforms that Mars had significant water at its surface during its early history, when conditions were much warmer than at present. Today, liquid water is not stable at the surface, but ice is observed at mid-to-high latitudes, and it presumably exists in the shallow subsurface as a relic of an earlier groundwater system. Therefore, given some reasonable geothermal gradient, liquid water is thought to be present at globally averaged depths of perhaps 3 to 5 km below the surface. Thus, the above logic would imply the need for a significant drilling and subsurface sampling capability to acquire samples of the Martian hydrosphere and any life forms that may be present in it. Ground ice is likely to be accessible at depths of a few tens to a few hundreds of meters depth, depending on latitude, and sedimentary rock at any depth down to a basement thought to be approximately 10 km.

Over the last two years, we have been working with NASA and others to develop an understanding of the requirements for Mars subsurface sampling and the technologies that will be needed to achieve it within the context of both robotic and human missions over the next two decades. The harsh low-temperature and pressure environment of the Martian surface, and the strong limitations on mass and power associated with missions, place demands on drilling and sampling technologies not previously seen in terrestrial applications. To better understand the problem, we recently completed for NASA a conceptual systems analysis for 200-m-depth drilling on Mars. This study analyzed a wide range of drilling technologies and selected those aspects that are best matched to the requirements of robotic subsurface sampling at Mars. (The study report is available at our Mars drilling Web site http://www.ees11.lanl.gov/mars/.) Based on these results, we are currently designing a 20-m-depth sampling concept for consideration for the 2007 Smart Lander mission, which will be the first opportunity for robotic subsurface sampling.

Drilling Support for the Environmental Restoration Program

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EES Division supports all aspects of drilling on LANL property for the ER and Groundwater Protection Programs. Ten deep wells have been drilled in the last two years. We are responsible for arranging the logistics and controlling the equipment for this effort. We work with drilling contractors and LANL facility managers to ensure that the drilling resources are assembled and properly deployed to accomplish the required work. We also maintain an inventory of frequently used parts and equipment, and we coordinate the ordering and delivery of specialized drilling equipment, well components, and backfill materials to minimize a work stoppage due to lack of equipment or materials. In addition, we repair, modify, and fabricate equipment for all aspects of the drilling program. Particularly noteworthy is our effort to reduce the health-related side effects of drilling. To address this problem, we have designed and fabricated equipment to efficiently contain, filter, and remove dust and cuttings from air-drilling operations.

Microhole Drilling and Instrumentation Technology

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We have collaborated with several oil companies to develop a subsurface exploration capability called microhole drilling and instrumentation technology. By reducing the drilled hole to the smallest size compatible with good drilling practice and continued instrument access, we can explore the Earth's subsurface at greatly reduced cost. This project is discussed in detail in the Research Highlights section.